

The Biodemography of Exceptional Survivorship and the Emergence of Super-Centenarians in Okinawa

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ABSTRACT

There has been a huge increase in the numbers of oldest-old (including centenarians) in post-war Japan and increasing research is now being focused on this burgeoning and frail population. Much has been learned about the oldest-old in recent years, however, much less is known about the population of extremely old persons reaching age milestones such as age 110. Recently, such people have been termed "super-centenarians" by gerontologists and they have begun to yield sufficient numbers to justify descriptive studies. The purpose of this study was to examine the population of super-centenarians from the long-lived prefecture of Okinawa, which has the highest centenarian ratio within Japan, and possibly the world. It was found that although most super-centenarians were institutionalized at age 105 and over, they had suffered from very little disease until late in life and most were ADL independent and living in the community at age 100. The oldest age-validated person in Okinawa at present is a 110 year old woman. Although currently bedridden, her case study revealed that she was living independently until age 105, consuming no medication and other than pneumonia at age 105 and cataract surgery at age 83, was healthy throughout her exceedingly long life. It is speculated that super-centenarians are genetically elite and therefore experience a delayed aging process, although lifestyle factors also appear to play a role in their longevity.

Keywords: super-centenarians, centenarians, biodemography, longevity, Okinawa

INTRODUCTION

Population aging is one of the most salient problems facing social welfare policy makers in advanced industrialized societies as well as a problem that many developing societies will face in the coming decades. In fact, the "oldest-old," usually defined as those aged 85 and above, is the fastest growing demographic group in most developed societies (Kinsella and Velkoff 2001; Vaupel 1997).

Since 1963, the Ministry of Health, Labour and Welfare has been keeping track of the numbers of persons achieving centenarian status across the nation (defined as persons who will have reached the age of 100 or more during the fiscal year). In the early 1960's these numbers were insignificant and centenarians were extremely rare with less than 200 persons in the whole of Japan (Ministry of Health, Labour and Welfare 2006). However, since that time, the drop in mortality at older ages has continued and the pace of increase among this age group has quickened. This has allowed for a "new generation" of oldest-old to appear, expected to surpass 30,000 in number in 2007 in Japan (Ministry of Health, Labour and Welfare 2006) and which may be setting the stage for the appearance of a generation of centenarians in developed countries (Vaupel 2000; Robine and Vaupel 2002; Coles 2004).

Moreover, decreased mortality among centenarians in the past few decades has pushed back the boundaries of maximum life expectancy even further in developed countries such that centenarians are not nearly as rare as they used to be. At the tail end of the survival curve of the centenarian population now lies another newly emerging sub-group of extremely aged individuals. Gerontologists have recently deemed it necessary to define this even newer demographic group (aged 110 and over) as "super-centenarians" (Robine and Vaupel 2002; Willcox, Willcox, and Suzuki 2006).

An emerging field of inquiry that is becoming increasingly important for understanding the driving forces behind these vast increases in human life expectancy, as well as forecasting new trends in aging and identifying new strategies to further increase healthy and productive older populations is the field of biodemography, which integrates biological knowledge with demographic research on human longevity (Carey and Vaupel 2005; Gavrilov et al 2002).

Recently, super-centenarians from Okinawa and elsewhere have begun to yield

sufficient numbers to justify biodemographic studies. Therefore, this study set out to examine the biodemographic characteristics of super-centenarians from Okinawa including their numbers, gender, living situation, medical history, functional status and health habits, in order to shed light upon their current living situations and speculate upon possible reasons for their exceptional longevity.

SUBJECTS AND METHODS

The numbers of people aged 99 and over in Okinawa and Japan were analyzed through record searches of Okinawa prefecture and Japan Ministry of Health, Labour and Welfare databases on centenarians over the years 1963 to 2006. Socio-medical and demographic variables including gender, physical (ADL) status, medical history and present living situation for past and present super-centenarians in Okinawa, were explored through interviews with family members. Case study design was employed for the oldest, age-verified person from Okinawa prefecture. Informed consent was received from all study participants and permission granted from local municipalities to review private documents such as the resident register.

RESULTS

As shown in Figure 1 below, the number of centenarians has increased rapidly throughout Japan during the past three decades. In 1963 there were only 153 centenarians in Japan but their numbers had grown to 28,395 by 2006. Women made up 85% of the total numbers of centenarians in 2006 and have fluctuated between a low of 78% and a high of 87% of total numbers since data began to be collected in 1963.

Figure 1: Centenarian Numbers in Japan from 1963 to 2006

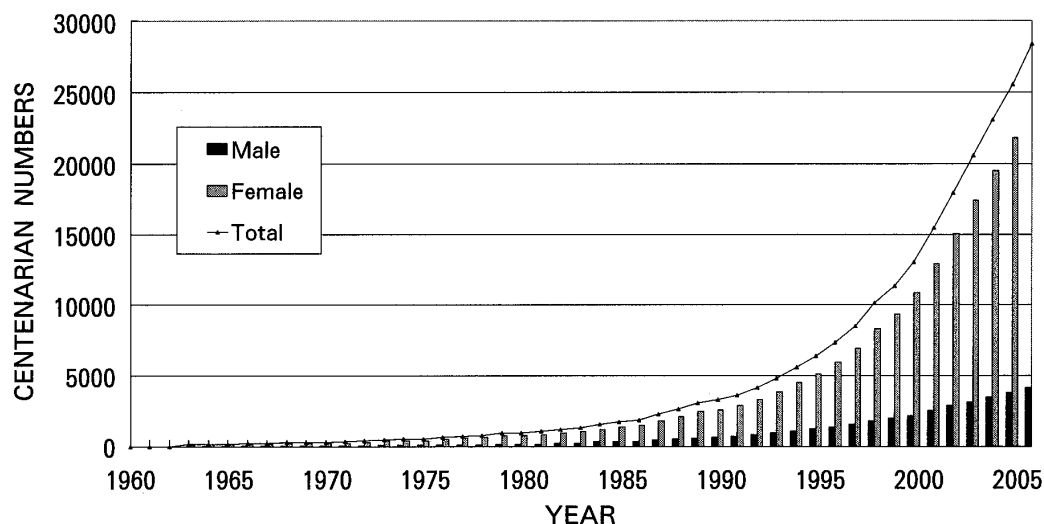


Figure 2 below reveals that there were no centenarians recorded in 1963 and the first centenarian did not appear until the year 1966 in Okinawa. However, by the year 2006 they had increased to 740 persons and reached 54 per 100,000 population, with 90% women. This is the highest reported centenarian prevalence in Japan as well as one of the highest female to male ratios.

Figure 2: Centenarian Numbers in Okinawa from 1963 to 2006

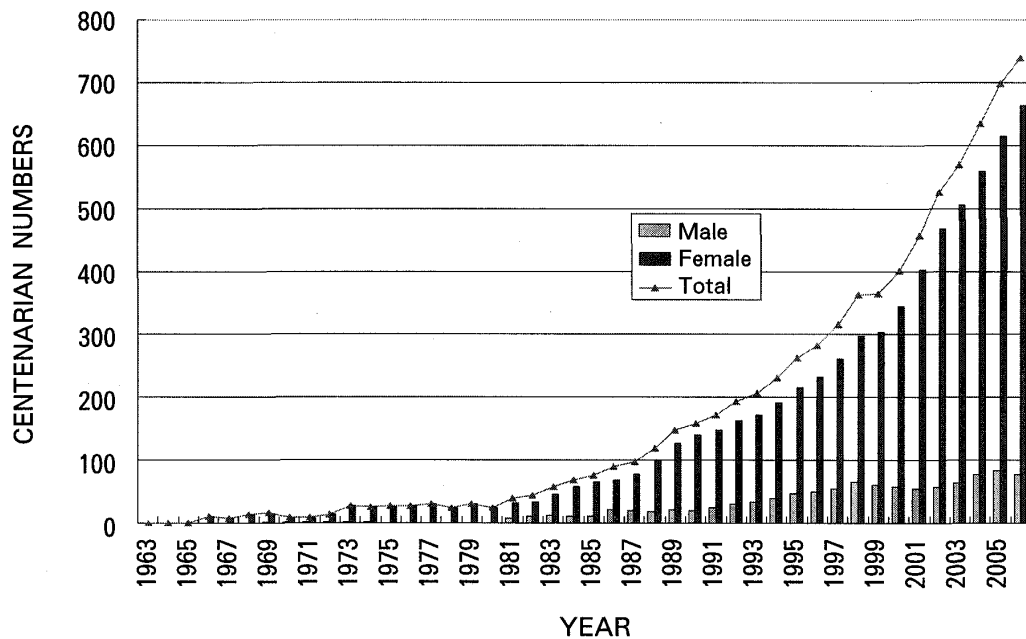
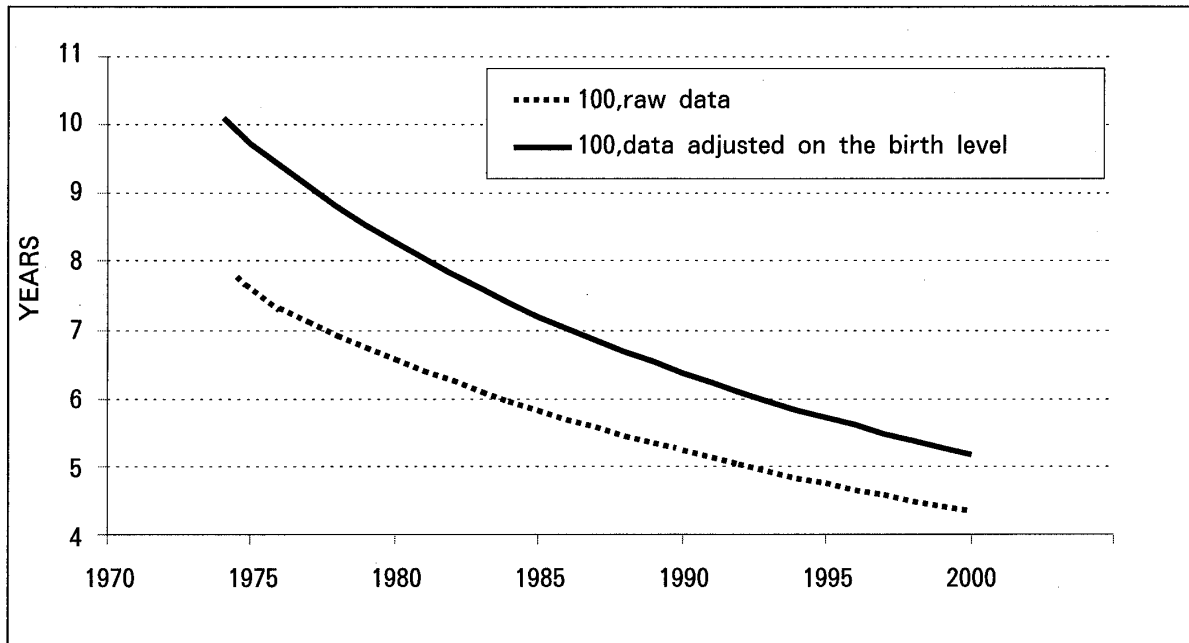


Figure 3 below reveals that the rate of increase in the centenarian population is itself increasing. For example, in less than three decades, the centenarian doubling time (defined as the amount of time it takes for the centenarian population to double) decreased from around 10 years in the early 1970`s to approximately 5 years by the beginning of the 21st century. This finding is after adjusting for the increase in birth rates that took place during this period and therefore quite robust. This finding is suggestive that major changes in society (i.e. health care, medical technology and progress, public health infrastructure, etc.) rather than merely larger birth cohorts, are largely responsible for this increase.

Figure 3: Rate of Increase in Centenarian Population in Japan 1970-2000



(Adapted from Robine et al 2003)

In 1966 the oldest person in Okinawa prefecture was 100 years old. It was not until 1991 that super-centenarians made their first appearance in Okinawa (see Figure 4 below) and no one has reached an age at death higher than 112 years. As of early 2007, the age of the oldest living person in Okinawa whose age has been properly documented, was a 110 year old woman. Currently, the oldest living person in the world is 114-year-old Yone Minagawa of Fukuoka. To put these findings in perspective, records indicate that the longest properly documented lifespan was that of Jeanne Calment of France (1875-1997), who was aged 122 years at time of death (Los Angeles Gerontology Research Group 2007; Robine and Allard 1998). This is in contrast to the presently disputed claim of 120 years for the oldest man ever, Shigechiyo Izumi of Tokunoshima, Kagoshima prefecture. While currently still recognized by *Guinness Book of World Records*, gerontologists in Japan and around the world have suggested that his koseki was not correct but in fact confused with an older brother's who died at a young age (Robine and Saito 2003). According to Figure 4 the maximum age at death has been rising in both Okinawa and Japan since the 1960's (if the contentious case of S. Izumi is excluded). This is in concert with most industrialized countries with high quality data, such as Sweden, which show a rise in the oldest age at death over the past few decades (Wilmoth et al 2000).

Figure 4: Maximum Life Expectancy in Okinawa and Japan 1972-2006

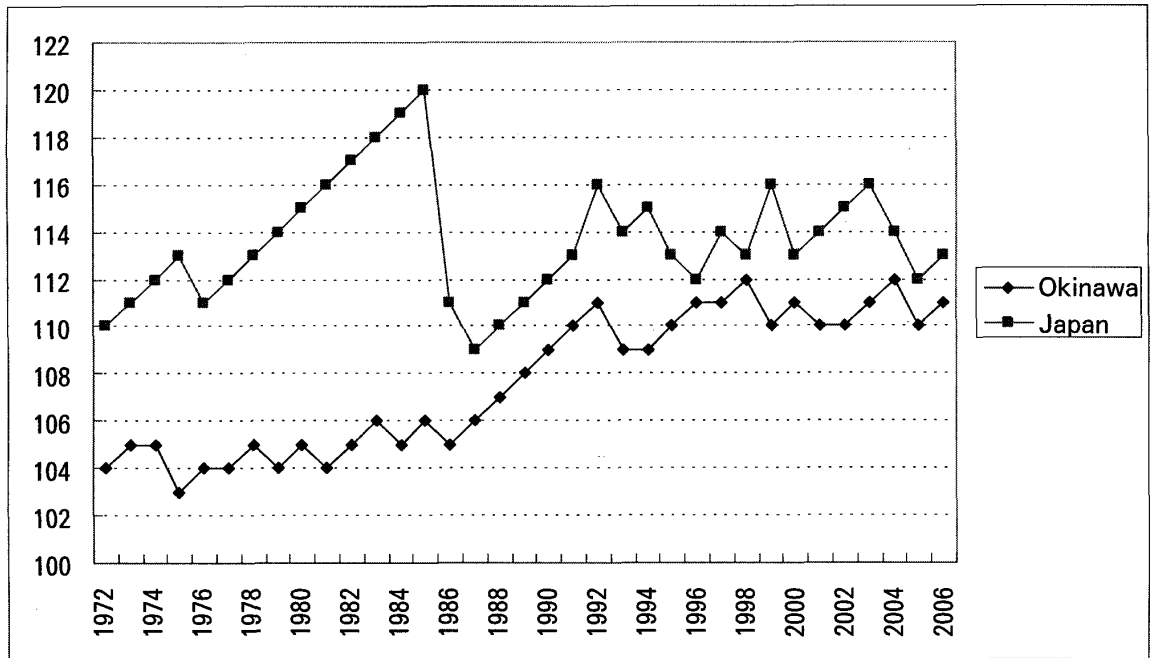


Table 1 (below) shows that most centenarians are in the 100 year age group with the 110 year age group less than 1% of the total, with only 33 people (2 men and 31 women) in the whole of Japan. One person (age 111) from this group was from Okinawa prefecture at time of counting but our records indicate that she has a mistake in her koseki and is actually aged 101.

Table 1: Centenarians in Japan by Age Group in 2006

Age	Male	Female	Total
100	1,804	9,310	11,114
101	1,046	6,043	7,089
102	619	3,724	4,343
103	355	2,340	2,695
104	161	1,335	1,496
105	88	745	833
106	44	375	419
107	13	186	199
108	11	110	121
109	7	46	53
110	1	22	23
111	1	5	6
112	0	3	3
113	0	1	1
114	0	0	0
115	0	0	0
Total	4,150	24,245	28,395

Table 2 (below) shows mortality rates for centenarians in Okinawa to have dropped for women since the 1960`s. The female average from 1966 to 1971 was 39.3 % while the same five year average from 1998 to 2003 was only 26.5 %. However, the small numbers warrant extreme caution in making conclusions. For men, numbers are too few to look for even tentative trends. However, mortality rates were higher for men aged 100 to 104 (1998 to 2003) compared to women at 34.6%. Mortality at age 105 and over was too small to make any conclusions.

Table 2 : Mortality Rates at Ages 100-104 in Okinawa

Year	Female		Male	
	Adjusted Mortality	Crude Mortality	Adjusted Mortality	Crude Cortality
1966	0.39	0.40	-	-
1967	0.37	0.38	-	-
1968	0.35	0.36	0.00	0.00
1969	0.57	0.58	0.49	0.50
1970	0.19	0.20	0.00	0.00
1971	0.49	0.50	0.0	0.00
1988	0.22	0.23	0.29	0.29
1989	0.33	0.34	0.36	0.37
1990	0.29	0.30	0.38	0.39
1991	0.33	0.34	0.38	0.39
1992	0.30	0.31	0.23	0.24
1993	0.29	0.30	0.27	0.28
1994	0.30	0.31	0.33	0.34
1995	0.23	0.24	0.35	0.36
1996	0.30	0.30	0.25	0.26
1997	0.26	0.27	0.43	0.44
1998	0.31	0.32	0.23	0.24
1999	0.26	0.27	0.34	0.35
2000	0.29	0.29	0.40	0.42
2001	0.26	0.27	0.36	0.37
2002	0.25	0.25	0.37	0.38
2003	0.22	0.23	0.31	0.32

Table 3 (below) shows that there have been 18 recorded super-centenarians in Okinawa since data began to be gathered by the Ministry of Health, Labour and Welfare. The first super-centenarian did not appear until 1992 and no one has survived longer than 112 years. However, not all super-centenarian ages have been validated and, as indicated earlier, the current oldest person in Okinawa (alleged to be aged 111) is of dubious validity. Therefore, we currently accept the oldest person in Okinawa to be a 110 year old woman whose case has been thoroughly age-validated through extensive family interviews and record checking.

Table 3: Super-Centenarians in Okinawa 1963-2006

Age of Death	Male	Female
110	1	6
111	0	7
112	1	3
113	0	0
Total	2	16

Tables 4 and 5 (below) record the socio-medical and functional characteristics of nine super-centenarians from Okinawa and from one case study. Some common trends can be observed. As can be seen from the tables, most of them were women who had little education. Most lived with family at the age of 100 years but by the time they were 110 years old they had moved into a long-term care facility or hospital. Most appear to have delayed diseases until very late in life and did not suffer from a major disease until aged 105 and over, except for cataracts which most had experienced in their later years (aged 80 and above). As they aged, some, but not all, gradually developed cognitive impairment. Most became liable to catch infectious diseases such as pneumonia, which is the most common cause of death in centenarians (Bertstein et al 2004). Most of them were ADL independent at the age of 100 but they gradually lost functionality so that by age 110 years old they were in need of major care support. Less than half smoked and those that did started later in life (usually after 50) and tended to smoke 10-20 cigarettes per day. Only 3 of 9 super-centenarians had a history of drinking alcohol and they tended to be social drinkers who drank little. 3 of 9 super-centenarians never drank or smoked at all during their lifetimes.

Table 4: Socio-Medical Characteristics of Super-Centenarians in Okinawa

Characteristic	Value
Sex (n=9) Female Male	8 1
Education (years)(n=7) 0 ≤ 8 9-12 > 12	4 2 1 0
Place of Birth (n=9) North area Central area South area Remote Island area	1 3 2 2
Living Situation (n=9) (age 100) With family Nursing home Hospital	6 2 1
Living Situation (n=7) (age 110) With family Nursing home Hospital	1 4 2
Medical History (n=9) (average age 105) Cancer Stroke Heart disease Respiratory disease Fracture (hip) Hypertension Hyperlipemia Diabetes mellitus Cataracts Cognitive impairment Pneumonia Malaria Dropsy Anemia	0 0 1 1 2 1 0 0 5 4 4 1 3 2

Table 5: Functional Status of Super-Centenarians in Okinawa

Characteristic	Value
Functional Status (ADL) (n=9) (age 100) Completely dependent (<11) Partially dependent (12-22) Independent with difficulty (23-33) Independent but slow (34-44) Completely independent (45-55)	0 1 0 0 8
Functional Status (ADL), (n=5) (age 110) Completely dependent (<11) Partially dependent (12-22) Independent with difficulty (23-33) Independent but slow (34-44) Completely independent (45-55)	0 5 0 0 0
Health Habits (n=9) Smoked Drank Alcohol Never drank or smoked	4 3 3

Case Study of Oldest Age-Validated Person in Okinawa: T.T.:

T.T. is the oldest age-validated person in Okinawa. She was born as the youngest child of five siblings on June 24, 1897. She was well-educated for the times, and went to school to the second grade of high school. She passed a *shihan gakkou* (teacher's college) exam, but was not able to attend due to objection from her parents. Her first marriage was at the age of 21 years old. Her husband divorced her because she did not conceive any children. Her second marriage was at 28 years old with a man 17 years older, but she did not bear a child with him either. However, she brought up the child of the ex-wife of the second husband. Her work history included housework, farming, and hat making as a side job. She had never experienced a major illness until she got pneumonia at age 105. Although she smoked a pack of cigarettes a day from her 30's to her 70's, it seems to have been her only negative health habit. She reportedly quit because she began coughing and her phlegm turned black which was very repugnant to her. Because her will was strong, she stopped immediately and never smoked again. She only drank alcohol in the form of medicinal herb liquor (garlic or plum liqueur) and only on social occasions. She had an operation on the right eye for a cataract at 83 years old. She practiced ancestor worship and looked after the family altar (*butsudan*) with care. Though her character was reported to be of the "nervous-type" she was forward looking and did not dwell on negative thoughts. She was conscientious about her health and exercised regularly, being an active walker. She was careful about her meals, eating frugally (*hara hachi-bu*), and thinking about the nutritional content of the foods. She was receiving excellent family care supplemented by a home helper who visited 5 times per week as well as a home visiting nurse who came to examine her twice a week. Table 5 (below) summarizes the life history, living situation and health habits of T.T. that may be connected to her exceptional longevity.

Table 6: Life History of T.T.

Life History of T.T.	
Date of Birth	June 24, 1897
Age at Interview	109.5 years old
Living situation	Own home (with oldest son)
Siblings	Youngest child of 5 siblings
Education	11 years. Passed Shihangakkou exam, did not attend
Marital status	Twice. First age 21, second age 28
Children/ Grandchildren	Never had a child. Brought up son of ex-wife of second husband. Five grandchildren.
Work History	Housework, farming, hatmaker
Medical History	Operation for cataract (age 83). Some cognitive impairment (from age 105). Hospitalized for pneumonia 40 days (age 105).
Medications	No medication. Nutritional drink only.
Health Habits: Smoking	One pack (20) per day from 30s to 70s
Alcohol	Medicinal herb liquor (garlic or plum liqueur), occasional drinker
Exercise	Active walker
Diet	Hara hachi bu, consumed a lot of vegetables and fish
Personality	Nervous but forward looking, doesn't dwell on negative
Socioeconomic Status	Middle class
Care (<i>Kaigo</i>)	Level 5. Family care supplemented by home helper (5 times per week) and nurse (2 times per week)

Interview with T.T. at 109.5 years old:

The interview took place in November 2006 with T.T. and her family with whom she was living (4 members in household). Her grandson and grandson's wife answered almost all the questions. Her son, aged 85, was in the hospital and his wife (*yome*) had recently passed away. Although past records indicated that T.T.'s functional status (ADL) was almost perfect (54/55 at 104 years old) until aged 105, her ADL dropped suddenly in March 2003, after a 40 day bout with pneumonia. At time of interview (aged 109.5) her ADL was 19/55 which indicated a bed-ridden condition. After her hospitalization for pneumonia she became bedridden and her care (*kaigo*) status has been at level 5 ever since (indicating need for total care). Otherwise, her health situation appears stable and she is not on any medication for any chronic condition. Her blood pressure usually stays even at around 110/50. Her declaration of intention is mostly clear although she appears to experience occasional hallucinations (about 3 times a month) according to the wife (*yome*) of her grandson. Her

hearing ability is minimal and this impairs communication and understanding of conversation.

She could say her date of birth, and was able to answer a question about how old she was four years ago (when we last visited). She also knew the animal year of her birth (*eto*). Family history reconstruction and her *koseki* (we received a copy) and her ability to state her Chinese astrological sign, date of birth and birth year were counted as verification of age. The wife of her grandson prepares her meals for her three times a day and assists her with eating. She has a good appetite, and usually finishes her meals, which is followed by a nutritional supplement. She receives occasional visits from relatives and neighbors and she can remember names and faces of close friends and relatives. Despite being bedridden she still consciously moves her own feet in order to get exercise. She prays for the health and well-being of family members before she eats her meals. Her care situation seems to be excellent with a home helper, visiting nurse, a home-visiting doctor of a nearby clinic (visits twice a month) and a short stay for five days per month in a care facility.

DISCUSSION

The oldest old (including centenarians) are the fastest growing demographic group in most industrialized societies (Kinsella and Velkoff 2001; Vaupel 1997; Thatcher 2001). Because of this fact, the number of centenarians has been increasing rapidly. Improved public health, increased care facilities and techno-medical interventions, will all likely contribute to an increasingly higher prevalence of centenarians and super-centenarians in the near future (Vaupel 2000; Willcox, Willcox and Suzuki 2006).

However, a super-centenarian is, as of yet, still an exceedingly rare phenomenon, as reaching the age of 110 years or more is achieved by only one in a thousand centenarians (based on European data), and in turn, only about one super-centenarian in 44 lives to turn 115 and only 2% of 110-year-olds can expect to survive five more years (Robine and Vaupel 2002). If one considers only the total worldwide number of living super-centenarians this number falls dramatically to less than 80 persons worldwide (Los Angeles Gerontology Research Group 2007) of which about 40% were living in Japan. At present, worldwide, there are no living persons older than 114 and despite many claims of ages 120 years or older it is almost certain that they

are false claims that lack proper documentation (Los Angeles Gerontology Research Group 2007; Robine and Allard 1998). The oldest properly documented (age-validated) case was that of Jeanne Calment of France who lived to be 122 years of age (Robine and Allard 1998).

It appears clear from previous studies that the majority of world claims to supercentenarian status do not have sufficient documentary support to be considered valid cases (Bennett and Garson 1983; Bourbeau and Lebel 2000; Coale and Kisker 1986; Kannisto 1988, 1994; Leaf 1982; Perls et al 1999; Mazess and Forman 1979; Medvedev 1986; Wang et al 1998). Some age misreporting may be intentional or conversely, it may be errors in recording. At a younger age, some people might have exaggerated their age to get married or to gain employment (Perls et al 1999). At older ages some people have exaggerated their ages to avoid military service (Medvedev 1986). Others (or their family members or communities) might claim extraordinary ages for secondary gain such as media attention and/or monetary incentives (Leaf 1982). Still other problems come about when there is poor record keeping (or even a lack of an age registration system) or social strife (eg. war, mass population movements, etc.) that causes loss or damage to records (Mazess and Forman 1979; Poulain and Naito 2004).

Due to the above problems with age misreporting among the oldest old it is vitally important to carry out proper age validation procedures such as the collection of a birth certificate or its equivalent (such as a *koseki* document), other documentation that may help to verify age throughout the life course, family reconstruction (kinship diagram that includes ages of birth and death of parents, siblings and children) and other culturally appropriate means (Wang et al 1998). In the case study of T.T., we received a copy of her *koseki* and she was able to correctly state both her date of birth and her birth year according to the Chinese astrological calendar (*eto*) and her life history and family reconstruction also supported her claims to supercentenarian status. Never the less, despite this case being verified, we have also found numerous mistakes (around 25% of centenarians) in the *koseki* of other centenarian subjects with some discrepancies as large as 10 years. However, that being said, most mistakes were within 1 to 2 years and some centenarians were actually found to be older than the official ages in their *koseki* indicating that the age registration system in Okinawa does not seem to suffer from a systematic bias towards age exaggeration as some researchers have suggested (Poulain and Naito

2004).

From the study of Okinawa's super-centenarians it appears that the majority were independently functioning at age 100 and experienced few diseases (cataracts were the most common disease mentioned) before one hundred years old suggesting a delayed aging process likely from good genes, although lifestyle factors such as low alcohol intake and low to moderate smoking also appeared to be important aspects of apparently healthy lifestyles of those interviewed. Centenarians in Okinawa have also been found to have an absence of many age-related diseases (Bernstein et al 2004; Willcox et al 2007a). Both genetic (Akisaka et al 1997; Takata et al 1987; Willcox DC et al 2006; Willcox BJ et al 2006) and lifestyle factors (Arakawa et al 2005; Goto et al 2003; Suzuki et al 2001; Sakihara 2004; Willcox et al 2001; Willcox et al 2007b) have been found to be important for longevity in Okinawa.

The compression of morbidity hypothesis (Fries 1980, 2005) predicts that, in order to achieve such extreme old age, centenarians delay or even escape diseases that would otherwise be deadly at younger ages (Perls 1997). However, phenotypic studies have not adequately characterized the prevalence and timing of age-related illnesses among those who achieve exceptional old age. In one such study, Evert et al (2004) found that American centenarians (similar to Okinawan centenarians) also tended to have an absence of many age-related diseases. When examining only the most deadly diseases of the American elderly population such as heart disease, cancer (non-skin), and stroke, it was found that 87% of male and 83% of female centenarian subjects delayed or escaped these diseases (Evert et al 2004).

However, despite superior life-long health even super-centenarians do not live forever and all of the Okinawan super-centenarian subjects were found to need high levels of care (most from age 105+). Moreover, it must be stressed that only half of Okinawa's super-centenarians were able to be contacted and interviewed. The possibility that there exists a bias towards healthier subjects, as is common in studies of the oldest-old, cannot be completely discounted (Andersen-Ranberg et al 2001).

The case study of T.T. revealed that she had followed a similar pattern as other super-centenarians in Okinawa with superior life-long health and eventual slow-down at around age 105, thus she too appeared to be part of the genetically elite. However, her consciousness about her health was also high and other than smoking

(which she quit upon negative symptoms appearing such as cough) she had practiced good lifestyle habits such as low alcohol intake, active walking, light eating (*hara-hachi-bu*), and a high consumption of fish and vegetables. These good health behaviors likely were part of the reason she maintained an ideal weight throughout her life and could be related to her longevity. Her positive attitude (not dwelling on the negative) may also have been a factor in her longevity.

Finally, good genes and lifestyle will only take one so far. It is speculated that T.T.'s excellent care environment (family care supplemented by *kaigo hoken*) from the time that she became bedridden at age 105 has been another extremely important factor that has helped her to achieve super-centenarian status and the position of the oldest (age-validated) person in Okinawa. No doubt, significant social welfare resources will need to be devoted to the care of this increasingly aged and frail population in the very near future.

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長寿のバイオ人口学と 沖縄のスーパー百寿者の出現

ドナルド クレイグ ウィルコックス

抄 録

日本では戦後、超高齢者（百寿者を含む）が莫大な増加をみせてきた。それとともに、この急増した弱者層をテーマにした論文も増えてきた。近年、超高齢者については多くの知見が得られてきたものの、超超高齢の、例えば110歳のような節目の年齢にまで達した人々についてはあまり明らかになっていない。最近、そのような人たちは、老年学者から「スーパー百寿者」と名付けられ、人数が増えてきており記述的研究が実施されるようになってきている。本研究の目的は、長寿県である沖縄に住むスーパー百寿者層を詳しく調べることであった。沖縄の百寿者率は全国一であり、世界一の可能性もある。研究結果によると、スーパー百寿者のほとんどが105歳以上になると施設に入所しているが、後年になるまで既往歴はほとんどなく、100歳当時のADL得点では自立者として地域に住んでいたことがわかった。現在、沖縄で年齢が証明されている最高齢者は110歳の女性である。現在は寝たきりだが、事例研究によると、その女性は105歳までは自立した生活を送っていたことがわかった。薬を服用することもなく、105歳で肺炎にかかったのと83歳で白内障の手術を受けた以外は非常に長きにわたりいたって健康であった。スーパー百寿者は遺伝的にエリートであり、そのことが老化プロセスを延期する一方で、ライフスタイルも長命の要因になっていることが考えられる。

キーワード：スーパー百寿者、百寿者、バイオ人口学、長寿、沖縄